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计算机科学大师探究设计原本



# 设计原本

(英文版)

计算机科学巨匠

Frederick P. Brooks

的思考

The Design of Design Essays from a Computer Scientist

(美) Frederick P. Brooks, Jr. 著

 机械工业出版社  
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# Preface

I write to prod designers and design project managers into thinking hard about the *process* of designing things, especially complex systems. The viewpoint is that of an engineer, focused on utility and effectiveness but also on efficiency and elegance.<sup>1</sup>

## Who Should Read This Book?

In *The Mythical Man-Month* I aimed at “professional programmers, professional managers, and especially professional managers of programmers.” I argued the necessity, difficulty, and methods of achieving conceptual integrity when software is built by teams.

This book widens the scope considerably and adds lessons from 35 more years. Design experiences convince me that there are constants across design processes in a diverse range of design domains. Hence the target readers are:

**1. Designers of many kinds.** Systematic design excluding intuition yields pedestrian follow-ons and knock-offs; intuitive design without system yields flawed fancies. How to weld intuition and systematic approach? How to grow as a designer? How to function in a design team?

Whereas I aim for relevance to many domains, I expect an audience weighted toward computer software and hardware designers—to whom I am best positioned to speak concretely. Thus some of my examples in these areas will involve technical detail. Others should feel comfortable skipping them.

**2. Design project managers.** To avoid disaster, the project manager must blend both theory and lessons from hands-on experience as he designs his design process, rather than just replicating

some oversimplified academic model, or jury-rigging a process without reference to either theory or the experience of others.

**3. Design researchers.** The study of design processes has matured; good, but not all good. Published studies increasingly address narrower and narrower topics, and the large issues are less often discussed. The desire for rigor and for “a science of design” perhaps discourages publication of anything other than scientific studies. I challenge design thinkers and researchers to address again the larger questions, even when social science methodology is of little help. I trust they will also challenge the generality of my observations and the validity of my opinions. I hope to serve their discipline by bringing some of their results to practitioners.

### Why Another Book on Design?

Making things is a joy—immensely satisfying. J. R. R. Tolkien suggests that God gave us the gift of subcreation, as a gift, just for our joy.<sup>2</sup> After all, “The cattle on a thousand hills are mine. ... If I were hungry, I would not tell *you*.”<sup>3</sup> Designing per se is fun.

The design process is not well understood either psychologically or practically. This is not for lack of study. Many designers have reflected on their own processes. One motivation for study is the wide gaps, in every design discipline, between best practice and average practice, and between average practice and semi-competent practice. Much of design cost, often as much as a third, is rework, the correction of mistakes. Mediocre design provably wastes the world’s resources, corrupts the environment, affects international competitiveness. Design is important; teaching design is important.

So, it was reasoned, systematizing the design process would raise the level of average practice, and it has. German mechanical engineering designers were apparently the first to undertake this program.<sup>4</sup>

The study of the design process was immensely stimulated by the coming of computers and then of artificial intelligence. The initial hope, long delayed in realization and I think impossible,

was that AI techniques could not only take over much of the drudgery of routine design but even produce brilliant designs lying outside the domains usually explored by humans.<sup>5</sup> A discipline of design studies arose, with dedicated conferences, journals, and many studies.

With so much careful study and systematic treatment already done, why another book?

First, the design process has evolved very rapidly since World War II, and the set of changes has rarely been discussed. Team design is increasingly the norm for complex artifacts. Teams are often geographically dispersed. Designers are increasingly divorced from both use and implementation—typically they no longer can build with their own hands the things they design. All kinds of designs are now captured in computer models instead of drawings. Formal design processes are increasingly taught, and they are often mandated by employers.

Second, much mystery remains. The gaps in our understanding become evident when we try to teach students how to design well. Nigel Cross, a pioneer in design research, traces four stages in the evolution of design process studies:

1. *Prescription* of an ideal design process
2. *Description* of the intrinsic nature of design problems
3. *Observation* of the reality of design activity
4. *Reflection* on the fundamental concepts of design<sup>6</sup>

I have designed in five media across six decades: computer architecture, software, houses, books, and organizations. In each I have had some roles as principal designer and some roles as collaborator in a team.<sup>7</sup> I have long been interested in the design process; my 1956 dissertation was “The analytic design of automatic data processing systems.”<sup>8</sup> Perhaps now is the time for mature reflection.

## What Kind of Book?

I am struck by how alike these processes have been! The mental processes, the human interactions, the iterations, the constraints,

the labor—all have a great similarity. These essays reflect on what seems to be the underlying invariant process.

Whereas computer architecture and software architecture each have short histories and modest reflections about their design processes, building architecture and mechanical design have long and honorable traditions. In these fields design theories and design theorists abound.

I am a professional designer in those fields that have had only modest reflection, and an amateur designer in some long and deep fields. So I shall attempt to extract some lessons from the older design theories and to apply them to computers and software.

I believe “a science of design” to be an impossible and indeed misleading goal. This liberating skepticism gives license to speak from intuition and experience—including the experience of other designers who have graciously shared their insights with me.<sup>9</sup>

Thus I offer neither a text nor a monograph with a coherent argument, but a few opinionated essays. Even though I have tried to furnish helpful references and notes that explore intriguing side alleys, I recommend that one read each essay through, ignoring the notes and references, and then perhaps go back and explore the byways. So I have sequestered them at the end of each chapter.

Some case studies provide concrete examples to which the essays can refer. These are chosen not because of their importance, but because they sketch some of the experience base from which I conclude and opine. I have favored especially those about the functional design of houses—designers in any medium can relate to them.

I have done functional (detailed floor plan, lighting, electrical, and plumbing) design for three house projects as principal architect. Comparing and contrasting that process with the process of designing complex computer hardware and software has helped me postulate “essentials” of the design process, so I use these as some of my cases, describing those processes in some detail.

In retrospect, many of the case studies have a striking common attribute: *the boldest design decisions, whoever made them, have accounted for a high fraction of the goodness of the outcome.* These bold decisions were made due sometimes to vision, sometimes to

desperation. They were always gambles, requiring extra investment in hopes of getting a much better result.

## Acknowledgments

I have borrowed my title from a work of a generation ago by Gordon Glegg, an ingenious mechanical designer, a charming person, and a spellbinding Cambridge lecturer. It was my privilege to lunch with him in 1975 and to catch some of his passion for design. His title perfectly captures what I am attempting, so I reuse it with gratitude and respect.<sup>10</sup>

I appreciate the encouragement of Ivan Sutherland, who in 1997 suggested that I grow a lecture into a book and who more than a decade later sharply critiqued the draft, to its great improvement. My resulting intellectual journey has been very rewarding.

This work has been possible only because of three research leaves granted by UNC-Chapel Hill and my department chairmen, Stephen Weiss and Jan Prins. I was most graciously welcomed by Peter Robinson at Cambridge, Mel Slater at University College London, their department chairmen, and their colleagues.

The NSF Computer and Information Science and Engineering Directorate's Science of Design program, initiated by Assistant Director Peter A. Freeman, provided a most helpful grant for the completion of this book and the preparation of the associated Web site. That funding has enabled me to interview many designers and to concentrate my principal efforts for the past few years on these essays.

I am deeply indebted to the many real designers who have shared their insights with me. An acknowledgments table listing interviewees and referees is an end piece. Several books have been especially informative and influential; I list them in Chapter 28, "Recommended Reading."

My wife, Nancy, co-designer of some of the work herein, has been a constant source of support and encouragement, as have my children, Kenneth P. Brooks, Roger E. Brooks, and Barbara B. La Dine. Roger did an exceptional review of the manuscript, providing dozens of suggestions per chapter, from concepts to commas.



I've been blessed by strong administrative support at UNC from Timothy Quigg, Whitney Vaughan, Darlene Freedman, Audrey Rabelais, and David Lines. Peter Gordon, Publishing Partner at Addison-Wesley, has provided unusual encouragement. Julie Nahil, Full-Service Production Manager at Addison-Wesley, and Barbara Wood, Copy Editor, have provided exceptional professional skills and patience.

John H. Van Vleck, Nobel-laureate physicist, was Dean of Harvard's Division of Engineering and Applied Science when I was a graduate student there, in Aiken's lab. Van Vleck was very concerned that the practice of engineering be put on a firmer scientific basis. He led a vigorous shift of American engineering education away from design toward applied science. The pendulum swung too far; reaction set in; and the teaching of design has been contentious ever since. I am grateful that three of my Harvard teachers never lost sight of the importance of design and taught it: Philippe E. Le Corbeiller, Harry R. Mimno, and Howard H. Aiken, my adviser.

Thanks and praise to The Great Designer, who graciously grants us the means, the daily sustaining, and the joys of subcreation.

Chapel Hill, NC  
November 2009

## Endnotes

1. The caption for the book cover is based on Smethurst [1967], *The Pictorial History of Salisbury Cathedral*, who adds, "... Salisbury is thus the only English cathedral, except St. Paul's, of which the whole interior structure was built to the design of one man [or one two-person team] and completed without a break."
2. Tolkien [1964], "On Fairy Stories," in *Tree and Leaf*, 54.
3. Psalm 50:10,12. Emphasis added.
4. Pahl and Beitz [1984], in Section 1.2.2, trace this history, starting in 1928. Their own book, *Konstruktionslehre*, through seven editions, is perhaps the most important systematization. I distinguish study of the *design process* from rules for design in any particular medium. These are millennia older.

5. The major monograph, tremendously influential, was Herbert Simon's *The Sciences of the Artificial* [1969, 1981, 1996].
6. Cross [1983], *Developments in Design Methodology*, x.
7. A table of the specific design experiences is included in the appendix materials on the Web site:  
<http://www.cs.unc.edu/~brooks/DesignofDesign>.
8. Brooks [1956], "The analytic design of automatic data processing systems," PhD dissertation, Harvard University.
9. I thus do not contribute to the design methodologists' goal as stated in [http://en.wikipedia.org/wiki/Design\\_methods](http://en.wikipedia.org/wiki/Design_methods) (accessed on January 5, 2010):

*The challenge is to transform individual experiences, frameworks and perspectives into a shared, understandable, and, most importantly, a transmittable area of knowledge. Victor Margolin states three reasons why this will prove difficult, [one of which is]:*

*'... Individual explorations of design discourse focus too much on individual narratives, leading to personal point-of-view rather than a critical mass of shared values.'*

To this I must plead, "Guilty as charged."

10. Glegg [1969], *The Design of Design*.

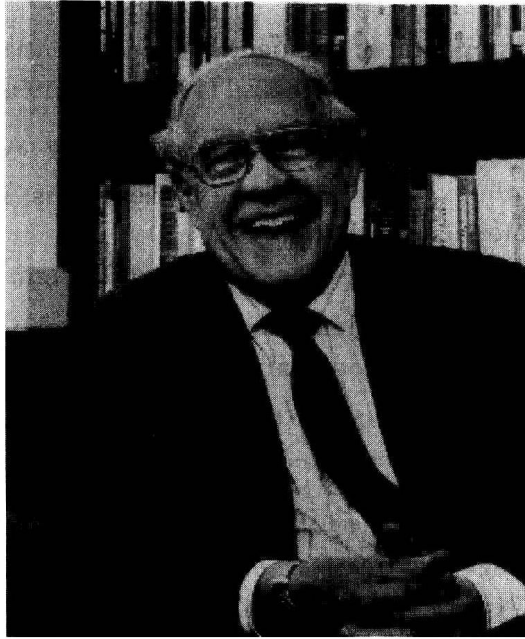


Photo credit: © Jerry Markatos

## **ABOUT THE AUTHOR**

Frederick P. Brooks, Jr., is Kenan Professor of Computer Science at the University of North Carolina at Chapel Hill. He is best known as the “father of the IBM System/360,” having served as project manager for its development and later as manager of the Operating System/360 software project during its design phase. For this work, he, Bob Evans, and Erich Bloch were awarded the National Medal of Technology in 1985. Earlier, he was an architect of the IBM Stretch and Harvest computers.

At Chapel Hill, Dr. Brooks founded the Department of Computer Science and chaired it from 1964 through 1984. He has served on the National Science Board and the Defense Science Board. His current teaching and research is in computer architecture, interactive computer graphics, and virtual environments.

# Contents

Preface .....	iii
<b>I Models of Designing .....</b>	<b>1</b>
Chapter 1 The Design Question .....	3
Chapter 2 How Engineers Think of Design— The Rational Model .....	13
Chapter 3 What’s Wrong with This Model? .....	21
Chapter 4 Requirements, Sin, and Contracts .....	39
Chapter 5 What Are Better Design Process Models? .....	51
<b>II Collaboration and Telecollaboration .....</b>	<b>61</b>
Chapter 6 Collaboration in Design .....	63
Chapter 7 Telecollaboration .....	89
<b>III Design Perspectives .....</b>	<b>103</b>
Chapter 8 Rationalism versus Empiricism in Design .....	105
Chapter 9 User Models—Better Wrong than Vague .....	113
Chapter 10 Inches, Ounces, Bits, Dollars— The Budgeted Resource .....	119
Chapter 11 Constraints Are Friends .....	127
Chapter 12 Esthetics and Style in Technical Design .....	139
Chapter 13 Exemplars in Design .....	153
Chapter 14 How Expert Designers Go Wrong .....	167
Chapter 15 The Divorce of Design .....	175
Chapter 16 Representing Designs’ Trajectories and Rationales .....	185

<b>IV</b>	<b>A Computer Scientist's Dream System for Designing Houses</b> .....	<b>201</b>
Chapter 17	A Computer Scientist's Dream System for Designing Houses—Mind to Machine .....	203
Chapter 18	A Computer Scientist's Dream System for Designing Houses—Machine to Mind .....	219
<b>V</b>	<b>Great Designers</b> .....	<b>229</b>
Chapter 19	Great Designs Come from Great Designers .....	231
Chapter 20	Where Do Great Designers Come From? .....	243
<b>VI</b>	<b>Trips through Design Spaces: Case Studies</b> .....	<b>257</b>
Chapter 21	Case Study: Beach House "View/360" .....	259
Chapter 22	Case Study: House Wing Addition .....	279
Chapter 23	Case Study: Kitchen Remodeling .....	297
Chapter 24	Case Study: System/360 Architecture .....	313
Chapter 25	Case Study: IBM Operating System/360 .....	331
Chapter 26	Case Study: Book Design of <i>Computer Architecture: Concepts and Evolution</i> .....	347
Chapter 27	Case Study: A Joint Computer Center Organization: Triangle Universities Computation Center .....	355
Chapter 28	Recommended Reading .....	367
	Acknowledgments .....	371
	Bibliography .....	375
	People Index .....	393
	Subject Index .....	401

I

# Models of Designing



# 1

## *The Design Question*

*[New ideas would come about] by a connexion and transferring of the observations of one Arte, to the uses of another, when the experience of several misteries shall fall under consideration of one mans minde.*

SIR FRANCIS BACON [1605], *THE TWO BOOKS OF THE PROFICIENCE AND ADVANCEMENT OF LEARNING*, BOOK 2, 10

*Few engineers and composers ... can carry on a mutually rewarding conversation about the content of the other's professional work. What I am suggesting is that they can carry on such a conversation about design, . . . [and then] begin to share their experiences of the creative professional design process.*

HERBERT SIMON [1969], *THE SCIENCES OF THE ARTIFICIAL*, 82

**Spiral staircase**

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## Is Bacon Right?

Sir Francis Bacon's hypothesis is our challenge. Are there invariant properties of the design process itself, properties that hold across a wide range of media of design? If so, it seems likely that designers in one medium would collectively grasp some of these principles more clearly than other designers, through struggles that are peculiarly difficult for that medium. Moreover, some media, such as buildings, have longer histories of both design and meta-design—"the design of design." If all this is true—and if Bacon's conclusion is true—designers in different media can expect to learn new things about their own several crafts by comparing their experiences and insights.

## What Is Design?

The *Oxford English Dictionary* defines the verb *design* as

*To form a plan or scheme of, to arrange or conceive in the mind . . . for later execution.*

The essentials of this definition are *plan, in the mind, and later execution*. Thus, a design (noun) is a created object, preliminary to and related to the thing being designed, but distinct from it. Dorothy Sayers, the English writer and dramatist, in her magnificent and thought-provoking book *The Mind of the Maker*, breaks the creative process out further into three distinct aspects. She calls them the Idea, the Energy (or Implementation), and the Interaction,<sup>1</sup> that is,

1. The formulation of the conceptual constructs
2. Implementation in real media
3. Interactivity with users in real uses

A book, in this conception, or a computer, or a program, comes into existence first as an ideal construct, built outside time